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HANDBOOK OF ATOMIC WEAPONS FOR MEDICAL OFFICERS

PREPARED BY THE ARMED FORCES MEDICAL POLICY COUNCIL

FOR

DEPARTMENTS OF THE ARMY, THE NAVY, AND THE AIR FORCE

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DEPARTMENTS OF THE ARMY, THE NAVY, AND THE AIR FORCE

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Chief of Staff,
United States Army

OFFICIAL:
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Major General, USA
Acting The Adjutant General

LAMONT PUGH
Chief of the Bureau of Medicine and Surgery
Department of the Navy

HOYT S. VANDENBERG
Chief of Staff,
United States Air Force

OFFICIAL:
K. E. THIEBAUD
Colonel, USAF
Air Adjutant General

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FOREWORD

The "Handbook of Atomic Weapons for Medical Officers" has been prepared as a joint project by a Task Group of the Armed Forces Medical Policy Council, composed of Medical Officers of the Army, Navy, and Air Force, and is published under the auspices of the Armed Forces Special Weapons Project.

It is the purpose of this handbook to provide a concise reference on atomic weapons effects of interest to medical personnel in the Armed Forces. It is intended that the contained information will serve as a guide in providing optimal medical care in a situation resulting from use of an atomic weapon.

The presence of radioactivity not only adds to the duties of the Medical Officer in providing adequate medical care, but also imposes additional problems of judgment and advisory consultation. This handbook presents information for use by the physician with the understanding that recommendations based upon its usage are, as always, subject to command decision.

Section I consists of general background information concerning atomic weapons effects with emphasis on the biological effects of ionizing radiation relating to the combat effectiveness of Armed Forces personnel. Section II consists of operational aspects for guidance under field military conditions. Section III consists of a compilation

of safety regulations which apply to routine industrial and laboratory utilization of radioactive material, and is presented for reference in view of current interest in this problem.

HERBERT B. LOPER
Brigadier General, USA
Chief, AFSWP

RICHARD L. MEILING
Chairman, Armed Forces Medical Policy Council

GEORGE E. ARMSTRONG
Major General
The Surgeon General, U. S. Army

LAMONT PUGH
Rear Admiral (MC), USN
Surgeon General, U. S. Navy

HARRY G. ARMSTRONG
Major General, USAF
Surgeon General, U. S. Air Force

CONTENTS

SECTION I
ATOMIC WEAPONS EFFECTS

1. CATEGORIES

This discussion of weapons' effects includes three categories. The first two, blast and thermal, are concerned with phenomena similar to those observed in high-explosive and incendiary type weapons. The third category deals specifically with ionizing radiation. While this arbitrary categorical separation facilitates the discussion of the problems, it must be remembered that the effects are simultaneous and a casualty could be the victim of multiple injuries.

2. BLAST EFFECTS

a. Blast effects are divided into the primary, or direct blast effect and the secondary, or indirect effect, due to flying debris, flying glass and structural collapse. In the atomic explosion, the primary blast does not exhibit the trip-hammer type of positive pressure wave found in ordinary high-explosive detonations, but is rather a violent wind of relatively long duration (approximately one second). Peak overpressures of 3 pounds per square inch will completely demolish ordinary residential construction whereas pressures up to 100 pounds per square inch are required to cause significant internal damage to the human body. This latter pressure is not attained even at ground zero following a nominal atomic bomb detonation. However, overpressures of 3 p.s.i. are produced

out to nearly 1½ miles from the nominal atomic bomb ground zero.

b. The amount and distribution of the secondary blast effects are dependent on the distance from the explosion, and the clinical results are the expected multiple contusions, lacerations, and fractures. The contusions and fractures present no special problems of importance except in their combination with other simultaneous injuries. There is a high incidence of lacerations due to flying glass. The fragments are often extremely small and multiple.

c. Treatment of these casualties presents no new problem; however, the vast number of casualties is a problem seen only in disaster medicine. Emphasis on intensive treatment is advisable to effect rapid healing, and thus minimize possible complications of radiation sickness.

3. THERMAL EFFECTS

a. Thermal radiation effects are divided according to the method of production into primary (flash) burns and secondary (flame) burns. It is emphasized that these burns in no way differ from burns caused by conventional weapons.

b. Primary thermal radiation effects are due to absorption of energy with large components of infra-red and visible wave lengths (with a very small component of ultra-violet) applied during a brief exposure, and result in flash-type or profile burns since they occur only on the surface facing the detonation. The thermal effects are related to the distance from the center of the explosion and atmospheric conditions. In Japan, the most severe

burns were noted within a ½-mile radius, with diminishing to negligible effects at a 2½-mile radius. Burns were modified by shielding, shading of structures, and angle of incidence. At distances greater than three-fourths of a mile, in many cases clothing served as adequate protection. A greater degree of protection was afforded by loose fitting, light colored materials. Dark colored clothing absorbed heat, thereby transmitting it to the body or bursting into flame. Burns varied from mild erythema without vesication occurring usually beyond 2½ miles, to severe second and third degree burns closer to the center. The second degree burns usually showed an intense erythema within a few days, then showed increased pigmentation and darkening which persisted for varying periods of time. Second degree burns frequently involved large areas of body surface and were similar to "moderate-temperature" burns except that the associated mortality was not as high as might have been expected. Vesication often appeared within a few minutes after exposure. Beyond 2½ miles from ground zero, burns were insignificant and beyond 1¾ miles, very few burns required treatment. Improper healing of these burns was influenced by lack of treatment. Common sequelae were contractures and keloid formation. Half of the Japanese deaths attributed to burns occurred within the first week and three-fourths occurred within 2 weeks. It can be stated that it requires 3 cal/cm^2 delivered in a 3-second period of time to produce a partial thickness (second degree) burns of human skin. It is to be noted that 9 cal/cm^2 is required to ignite cotton and 14

cal/cm² is required to ignite wool. (See table II).

c. Secondary (flame) burns occurred in Japan, associated with secondary fires which developed in the city buildings, as well as flame burn due to actual burning of clothing. These secondary burns were responsible for many fatalities, especially in persons who were so injured by secondary blast effects that they could not escape.

d. The treatment of burns may represent the Medical Officer's biggest problem. Under field conditions unshielded troops will sustain large numbers of burns involving exposed body surfaces, i.e., face and hands. Issue combat uniforms will completely protect covered body areas at distances in excess of 1500 yards. Under field conditions, the initial treatment should consist of an occlusive dressing and sedation as required. The important consideration is evacuation to medical facilities, where surgical technique and extensive supportive treatment are available. If the burned area involves over 20 percent of the body surface or if there are medical indications, fluid replacement should be started before evacuation. Extensive research is being conducted for the development of self-treatment methods and materials and also more efficient standardized methods leading to efficient mass therapy.

e. It must be emphasized that mechanical and thermal injuries constituted the great majority of casualties, and thus the care of these casualties will require the majority of emergency care in the event of an atomic bomb detonation.

4. IONIZING RADIATION EFFECT

a. Approximately 25 percent of the total casualties in Japan showed effects of ionizing radiations, and of these, approximately one-third (8 percent) were due to radiation injury alone. In spite of this numerically minor role, the introduction of radioactivity as a military hazard warrants a thorough knowledge of its effects.

b. The damage or effect of ionizing radiation on tissue depends upon absorption of the energy of radiations by the tissue exposed. This transfer of energy occurs as a result of ionization although the exact biophysical and biochemical changes produced have not been delineated. The different radiations (alpha particles, beta particles, gamma rays, neutrons) produce ionization by different mechanisms and to varying degrees, but the end result in the biological system is due to the absorption of the energy and thus is not specific for any given type of radiation, nor even for radiation itself. In other words, the cellular response does not differ qualitatively with different types of radiation. There is no satisfactory evidence of any primary effects of radiations on tissues other than damage or destruction. So-called stimulation by radiation is probably the result of physiological over-compensation for damage.

c. The variations in radiation effects which result from exposure to different types of radiation arise mainly from the differences in penetration and specific ionization of the radiations. As will be noted later, additional variation in tissue response is dependent upon individual tissue radiosensitivity. A few of the radiation characteristics are presented in tabular form for comparison:

Table I. Radiation Characteristics

Radiation		Energy range	Penetration: Air	Penetration: Tissue	Relative *ionizing* power
Alpha particle	Heavy, positively charged particle He++, He nucleus.	3–11 Mev *	Up to 8 cm.	0.01 cm	10,000
Beta particle	Light, negatively charged particle, electron.	Up to 3 Mev.	600 cm	0.2 cm	100
X- or Gamma rays	Electromagnetic radiation, uncharged wave length 5×10^{-10} to 10^{-7} cm. Velocity of the speed of light.	Up to 10 Mev.	Approx. 1 mile (absorbed exponentially in matter, thus no finite range.)	Several cm	1
Neutron	Neutral nuclear particle, mass = 1.	Up to 10 Mev.	Approx. ¾ mile	Several cm.	8

* Mev. = Million electron volts = work done when electron is accelerated by a potential difference of one million volts.

Table II. Summary of Nominal Air Burst Weapons Effects

Agent	Source	Characteristic	Flux	Time of arrival	Remarks
BLAST	Fission	Long positive pulse. Longer neg. phase.	50 p.s.i. at GZ* 3 p.s.i. at 1½ miles.	1 sec—1000 yds. 3 sec—1 mile 8 sec—2 miles	*a.* Direct—no significant body effect at this p.s.i. *b.* Indirect-important because even 3 p.s.i. will damage ordinary residential construction. Injuries therefore from flying and falling debris.

* GZ — Ground Zero — point on ground directly beneath detonation.

Agent	Source	Characteristic	Flux	Time	Remarks
BURN *a.* Flash	Fission Fireball	Visible and infra-red portions of spectrum. Very small proportion is ultra-violet.	50 cal/cm² at 1000 yds. 15 cal/cm² to 2000 yds. 3 cal/cm² to 3000 yds. in clear atmosphere. Haze decreases range.	50% in 1 sec. TOTAL in 3 sec.	3 cal/cm² delivered in 3 sec. produces partial thickness (2nd degree) burn. Clothing protects beyond 1,500 yds. Shadow protects.
b. Flame	Fires, Fire storm	Contact or radiant energy burn.	Not specific		Not distinctive.

Agent	Source	Characteristic	Flux	Time	Remarks
RADIO-ACTIVITY *a.* Prompt	Fission	Gamma, neutrons (small fraction of total radiation.)	600 r at 1300 yds. 400 r at 1400 yds. 100 r at 1 mile	50% in 1 sec. 80% in 10 sec. 100% in 90 sec.	Half thickness, i.e., will cut down flux by 50% ½″ lead 1″ steel 3″ concrete 5″ earth 8″ water
b. Delayed	Fireball cloud	Major portion of total gamma radiation produced.	Approx 20 r at 2000 yds.		Relatively "long time" of delivery makes shielding or evasive action possible.
c. No dangerous residual radio-activity from air burst.					

d. There are two types of radiation exposure, i.e., external and internal. These are differentiated by the position of the source with respect to the body. Although their effects are discussed separately, it must be remembered that under unusual circumstances both types of hazard may be present simultaneously.

e. In view of the dependence of the biological response upon the energy absorption within the cellular mechanisms, it is evident that the effects will be altered by varying amounts of energy absorbed, whether in terms of radiation flux or in exposures of small or large body volumes, i.e., local or total body irradiation.

5. BIOLOGICAL EFFECTS OF IONIZING RADIATIONS

a. The radiation damage of tissue results from energy changes in the cell or its immediate environment and observations suggest that the mechanisms involved may include interference with nucleus-cytoplasm biochemistry, changes in cellular membrane permeability, intercellular balances and possible formation of toxic chemicals. Microscopically observed cellular changes after irradiation include chromatin clumping or chromosome breaks, abnormal cellular division and mitosis, changes in cytoplasmic granularity, abnormal staining reactions and gross cellular changes, including swelling and cytolysis. These, as well as many other observed changes, probably represent multiple resultant manifestations of the primary damage produced by ionization.

b. Many factors are operable in effecting the

variations observed in biological materials subjected to irradiation. The composite cellular structure coupled with the random distribution of the radiation flux, necessarily introduces a factor of statistical probability into the reduplication of biological results under controlled experiments. In addition to this variable cellular response, changes in cellular environment may be of either primary or secondary importance in determining the observed effects. Changes in temperature, oxygen tension, acidity and alterations in the osmotic balance of the cellular environment also affect the radiosensitivity of certain tissues and biological systems.

c. The radiosensitivity of a given tissue can be predicted, within limits, under the general rule that a greater radiosensitivity is found in tissues which are either relatively unspecialized or exhibit rapid multiplication or active reproduction. As a corollary, highly differentiated tissues and those in a quiescent state of development are relatively radioresistant. In order of decreasing radiosensitivity, the following list may serve as a general guide:

(1) Lymphocytes
(2) Erythroblasts
(3) Germinal epithelium of testis
(4) Myeloblasts
(5) Intestinal crypt epithelium
(6) Ovarian germinal cells
(7) Basal layer of skin
(8) Connective tissue
(9) Liver
(10) Pancreas
(11) Kidney

(12) Bone
(13) Nerve
(14) Brain
(15) Muscle

d. Different species of animals show a particularly wide variation of response to identical radiation exposures. This requires the use of statistical methods in measurement of effects and conditions the application of results from one species to any other.

e. The effects of rate of delivery of a radiation exposure are variable, but are usually represented by (1) an accumulative effect which is dependent only on the total dosage, regardless of the rate, and (2) a decrease in the biological effect with decrease in the rate of exposure.

f. An additional consideration involves the spatial relationship between the tissue and the radiation source—in other words, the range, penetration, and absorption of the radiation must be related to the position of a tissue which can be damaged. For example, alpha particles produce intense ionization, but their range is such that they are stopped by the cornified layer of the skin and thus alpha emitters present no external hazard. If deposited in a vital tissue within the body, an alpha emitter can produce severe damage due to its associated ionizing radiations. High energy gamma rays have a far lesser ionizing power than alpha particles, but their penetrating ability makes gamma emitters a major external hazard.

6. RADIATION PATHOLOGY

Although this discussion of radiation pathology is divided according to organ systems, the order of mention does not indicate relative radiation response. It must be remembered that in view of the many variables in biological effect, any summarized description must be general in nature. Associated with the nonspecific effects of radiation, it follows that external and internal sources will differ in observed effects depending on the source location and the type and energy of the radiation. While the absorption of the energy by the biological entity probably is immediate, some resulting changes will be immediate and others may be delayed for weeks, months, or years. The effects may be acute or chronic. The following results can be observed following fairly intense radiation exposure and are based on effects noted in Japanese patients as well as animal experimentation.

a. Skin. With sufficient dosage erythema may appear within 48 hours, probably due to primary radiation effects, then reappear in cycles around the third and sixth weeks, the latter due probably to secondary effects. Early changes included decrease in epithelial mitosis, vascular dilation and mononuclear infiltration of the cutis. Later cycles showed desquamation, edema and vacuolation of basal cells, and later pigmentation. Cellular infiltration occurred around the hair follicles, sebaceous glands and sweat glands. Epilation occurred about the third week, with mitotic decrease, vacuoloation and occasionally necrosis of the fol-

licles. In animals with chronic radiation exposure, the epithelium showed thinning, drying and scaliness from lack of secretions, and mild trauma often resulted in persistent difficult-to-heal ulcers. Vessels showed telangiectasia and varying degrees of degeneration.

b. Gastro-Intestinal Tract

(1) Some of the earliest gross lesions were seen in the gastro-intestinal tract and these changes of discoloration, hyperemia, distension, increased secretion, and submucosal edema appeared before the usual hemorrhagic responses. Later changes included submucosal petechiae, pseudo-membrane formation and ulceration with localized hemorrhages. In the small intestine, sites of involvement might include tips of folds, diffuse mucosal processes centering in regions of lymphatic tissue concentration, and later extensive, almost universal, mucosal edema, ulceration and hemorrhage.

(2) Microscopic changes included abnormal cellular morphology in the epithelium with bizarre mitotic and developmental figurations. These cells showed early decrease in mitotic activity followed by swollen nuclei, clumped and abnormally staining chromatin.

c. Genitourinary Tract.

(1) The kidneys, ureters and bladder showed no effects of radiation except for secondary hemorrhagic manifestations. The effect on the prostate and the seminal vesicles was not notable.

(2) The testes showed early evidence of injury to the germinal epithelium in the form of necrosis and displacement of tissue into the tubules and decreased mitotic activity. Later observations indicated marked inflammatory reaction, considerable vascular change, atrophy and hyalinization of the tubules, and relative absence of germ cells. The resultant sterility is temporary in survivors.

(3) Changes in the ovaries were less marked and the only gross manifestation resulted from hemorrhagic phenomena. Histologically only a few atretic primary follicles were noted, and the absence of developing follicles was the rule. A temporary incidence of amenorrhea has been reported.

d. Lungs. The early changes of perivascular, parenchymal and pleural edema, proliferation of alveolar lining cells and hyaline membrane formation later developed into diffuse hemorrhagic and necrotic pneumonia.

e. Heart. The heart showed mainly secondary hemorrhagic changes consisting of epicardial, myocardial and subendocardial petechiae. Fatty degeneration, edema and cellular infiltration were seen in some instances.

f. Spleen. The marked sensitivity of lymphoid tissue to radiation resulted in extreme atrophy early after exposure, and the disappearance of lymphocytes left a characteristic stromal pattern.

The disappearance of germinal centers was at times preceded by local necrosis. The lymphatic tissue showed edematous swelling, hemorrhagic discoloration and friability. Atypical cells were noted, particularly in the mononuclear and lymphoblastic types. Plasma cells, mast cells, eosinophiles and reticular cells were increased in number. The lymphoid structure of the spleen exhibited the same changes as noted in the lymph nodes, resulting in decrease in follicular size and increase in trabeculation. Atypical large mononuclear cells were seen and evidence of phagocytosis of erythrocytes was noted in some cases.

g. Bone Marrow. The bone marrow suffered complete destruction of blood-forming elements, with subsequent reticular proliferation and development of plasma cells and lymphocytes rather than granulocytes. Later myeloid changes were followed by hyperplasia in some cases. All cases of death occurring within six weeks showed a severe leukopenia although a few cases developed a subsequent leukocytosis. A definite picture of anemia was present in most cases.

h. Bone. Irradiation of bone resulted in eburnation and local necrosis, usually without leukocytic cellular infiltration or sequestration. Osteoclasts and chondroplasts were decreased in number and the normal structural pattern of the epiphyseal region was occasionally altered.

i. Endocrines.

(1) In the pituitary large basophilic cells with considerable cytoplastic vacuolation appeared in a number of males who died

before the sixth week. In those who died in later periods, large basophiles were found, but only a few showed vacuolation.

(2) The adrenal cortex showed a decrease in lipoid content, and tended toward a definite thinning. The microscopic changes in the cortex included a granulation of the foamy cells, and the atrophy was most marked in the outer glomerulosa zone. Those foam cells which were present were usually found in the inner layer. The adrenal medulla presented no abnormal changes.

(3) The thyroid and pineal glands showed no marked changes.

j. Miscellaneous.

(1) Brain and nerve cells exhibited only secondary hemorrhagic or necrotic changes.

(2) Pancreatic changes were minimal, and were mainly limited to the appearance of abnormal mitoses in the islet cells.

(3) Effects of the radiation exposure on the liver and other visceral organs were questionable.

7. DIAGNOSIS OF RADIATION EXPOSURE

The clinical and laboratory findings resulting from exposure to radiation are functions of the amount of radiation, the rate of exposure, and the dosage absorbed in various parts of the body. Both acute and chronic effects may result from

either internal or external sources of radiation. While the overall effects of radiation can be described fairly accurately, it must be recalled that these changes in the body are a physiological response to damage from absorbed energy and are not pathognomonic of radiation exposure. The type and penetration of the radiation will determine the location of effect.

a. The symptomatology in man after exposure to radiation has been reported following the atomic bomb explosions in Japan, and those observations are bases for the summarizations of the clinical effects presented. A few hours following exposure to ionizing radiation, anorexia, nausea, and vomiting appeared, which lasted from 1 to 48 hours and then subsided for a variable latent period of days. The shorter the latent period, the more severe were the symptoms of recurrent anorexia, nausea, vomiting and diarrhea. Later mucous or bloody discharges from the body orifices and secondary hemorrhages occurred resulting in death. In general, the rapidity of onset of symptoms and the rapidity of progression of the illness were in direct proportion to the amount of radiation received. The duration of the latent period was inversely proportional to the degree of radiation exposure. With large doses the latent period may become very short or even disappear and death can occur within 24 hours. It is important to remember that with short latent periods, death may occur before the full radiation syndrome develops. The latent period is also modified by species and individual characteristics.

b. The hematologic responses to intense pene-

trating radiations are quite uniform, but exposure to less penetrating (low energy) radiations may result in blood changes which may be of short duration, slight or undetectable, even in the presence of severe superficial body damage. Beginning shortly after exposure to radiation, there is a prompt decrease in the total lymphocyte count, with its maximum effect within 24 to 72 hours, depending partially on the amount of radiation received. There is a simultaneous granulocytic leukocytosis which develops with the progressive lymphocytopenia for approximately 24 hours, then declines for 4 to 6 days, with a second slight activity which is associated with increased bone marrow activity. If the radiation exposure is sublethal, this activity is sustained and progressive, while with a lethal exposure, this activity is absent. In very large doses of radiation, the granulocytosis may not be observed. Not so regularly seen are reduction in the platelet count, morphological changes in the leukocytes and reduction in the erythrocyte count. Atypical erythrocytes and immature leukocytes begin to appear in the peripheral blood from 3 to 10 days after exposure. A strict schedule of changes following acute or chronic radiation cannot be compiled because of the marked "normal" variations in blood constituents in addition to the multiple variable factors associated with the radiation itself. As a guide, the following findings are presumptive evidence of excessive exposure in an individual exposed to chronic radiation:

(1) A persistent depression of leukocyte count below $4000/mm^3$.

(2) Persistent leukocytosis above 15,000 with absolute lymphocytosis.

(3) Relative lymphocytosis with low total white count (4000—6000) with return to normal after removal from radiation exposure.

(4) Increased mean corpuscular volume and mean corpuscular diameter.

(5) Reticulocyte count above 2 percent.

c. The description of the clinical symptomatology or radiation syndrome is facilitated by dividing into three categories the patients observed in Japan who suffered from radiation over-exposure. These divisions are inexact in their differentiation, but may present a guide to the clinical picture.

(1) Patients who died within the first 2 weeks showed histological evidence of radiation effects on the skin, gastro-intestinal tract, lymphoid tissue, bone marrow, or gonads, but these changes were not observed grossly or clinically. Nausea and vomiting were noted on the first day of exposure, followed by anorexia, malaise, severe diarrhea and thirst, and the development of fever. There was no epilation or purpura. Fever continued to rise and death occurred with the patient in delirium. The earlier the fever, the more severe the symptoms and the poorer the prognosis.

(2) Patients who died during the third to sixth weeks, or who survived the severe symptoms, showed the maximum changes in the anatomical and clinical results of radiation. Most prominent were epilation and the depressive effect on the bone marrow. The hemorrhagic and necrotizing lesions were comparable to those seen in aplastic anemia and agranulocytosis, and occurred in the gums, respiratory and gastro-intestinal tracts. The nausea and vomiting occurred on the day of exposure, followed by marked malaise. The patient then experienced a period of improvement which continued until about the second week, when epilation marked the beginning of the relapse phase. Malaise again appeared, followed by fever which increased in step-like fashion, onset of pharyngeal pain and often a bloody diarrhea. There was a profound anemia with low levels of leukocytes and platelets and a general debilitated condition which lasted, in some cases, for a long period of time.

(3) In a few individuals in which the bone marrow failed to recover, the debilitated condition and profound anemia, leukopenia and malaise continued and progressed, and the patients died after a chronic illness of extreme emaciation. In other words, associated with the apparent recovery of the bone marrow, the marked anemic picture disappeared but the patients later succumbed to intercurrent infections or complications such

as tuberculosis, lung abscess or pneumonia. Following is a summary of the clinical signs and symptoms which can be expected as a result of whole body gamma radiation delivered within 1 hour.

Table III. Clinical Radiation Illness

Days after exposure	Lethal exposure (Over 600 r)	Mid-lethal exposure (450 r) 50% deaths	Non-lethal exposure
0	Nausea & vomiting with 1–3 hrs.	Nausea & vomiting after 2–4 hours	Variable depending on individual
1	Generalized malaise	No definite symptoms	do.
2	Malaise & anorexia	do.	do.
3	Anorexia & nausea	do.	do.
4	Nausea & vomiting	do.	do.
5	Vomiting & diarrhea	do.	do.
6	Inflammation of mouth & throat	do.	do.
7	Fever	do.	do.
8	Rapid emaciation	do.	do.
9	Death	Beginning epilation	do.
10	Mortality probably 100%		do.
11			do.

Table III. Clinical Radiation Illness—Continued

Days after exposure	Lethal exposure (Over 600 r)	Mid-lethal exposure (450 r) 50% deaths	Non-lethal exposure
12			do.
13			do.
14			do.
15			do.
16			do.
17		Anorexia & malaise	do.
18			Beginning epilation
19		Fever	Anorexia & malaise
20		Mucosal inflammation	
21			Sore mouth
22			Pallor
23		Pallor	Petechiae
24			Diarrhea
25		Petechiae	Moderate emaciation
26		Mucosal hemorrhage	
27		Diarrhea	(Recovery unless complicated by previous poor health or super-imposed injuries or infections)
28			
29			
30		Rapid emaciation, Death, mortality probably 50%	

Note. These signs and symptoms suppose no medical intervention and ignore individual biological variations.

8. GENETIC EFFECTS

a. While the genetic effect of radiation perhaps has been over-emphasized in the nontechnical papers, it is thought that the probability of producing a mutation with a single ionizing event does exist. Little is known of the actual effects to be expected in man, but it is estimated that about 600 r would be required to produce significant mutation rate changes, and the fact of survival of an individual indicates a probable absorption of less than 450 r.

b. Naturally occurring and artificially produced mutations in man are approximately 95 percent lethal, or self-limiting, and of the 5 percent viable mutations, another 95 percent are deleterious and of these, approximately 96 percent are pertinent to other than sex chromosomes. Therefore no marked genetic or hereditary abnormalities are anticipated from the use of the atomic weapon in Japan.

9. PSYCHOLOGICAL EFFECTS

a. The psychological aspects of radiation injury cannot easily be simplified, thus emphasizing the problems of presentation and education. In controlled conditions, the value of maintaining exposures to radiations at levels below the maximum permissible dosage is obvious.

b. An understanding of the over-all as well as the specific problem of the hazard is necessary to permit an intelligent viewpoint. In war time, military hazards are multiple and encounters are planned with the realization of these hazards. Radiation is another of these hazards and must be considered in that light.

c. The radiation hazard must not be underestimated, but it must be evaluated in the consideration of the objective and included in the "calculated risk" of all hazards. Education and psychological training will serve to eliminate the misconceptions and blind fears about radiation.

10. THERAPY OF RADIATION CASUALTIES

a. At the present time, there is no specific therapy medication to be given to patients suffering from exposure to lethal or near lethal doses of ionizing radiation. This does not, however, indicate a futility of the therapeutic regime. It is known that in Japan where in most instances there was no treatment of any type, there were about 1000 survivors located within one-half mile of ground zero. Adequate symptomatic therapy will do much to reduce the morbidity and mortality of exposure to ionizing radiation. Animal experiments have shown that good nursing care will reduce the mortality significantly. Food, water, cleanliness, and adequate care of damaged skin areas will help considerably.

b. It has been found that many agents, if they are given before exposure to ionizing radiation, exert a protective effect upon the organism. These include shielding of bone marrow or spleen, cysteine, glutathione, atmosphere with diminished

oxygen tension, etc. It is obvious that these agents would be of little use in a tactical situation unless adequate warning of impending disaster were given. If such an alarm were sounded, it would be much wiser to exercise the principles of mass dispersion and protection rather than individual prophylactic therapeusis.

c. Recent experimentation indicates that symptomatic or supportive therapy includes antibiotics (especially those specific for the gram negative organisms), whole blood, coagulants where necessary, and parenteral feedings of fluid and nutrients. It is well to keep in mind that continued administration of antibiotics may lead to resistance in the organism involved. However, this can be obviated by the judicious combined or alternating use of the many antibiotics on hand, which include penicillin, streptomycin, chloramphenicol, aureomycin, and terramycin. Even though, as mentioned above, specific therapy for this syndrome is not available, adequate supportive therapy and the principles of antisepsis will do much to reduce the morbidity. This treatment has resulted in a significant reduction in mortality in experimental animals after exposures within the lethal range for that species.

11. PROTECTION

a. Protection from external radiation hazards depends upon two main factors—distance from the source based on the inverse-square law of intensities, and the interposition of shielding materials between the source and the subject, based on

the absorption of the radiation by the material. (See table II.)

b. Personnel protection from the initial radiations of the bomb can be afforded by specially designed structures and incidentally by any material providing shielding. The wearing of protective outer clothing in a contaminated area serves to prevent surface contamination of the individual but provides little protection from the radiations. In dusty contaminated areas, the use of respiratory protective measures, elimination of eating, drinking, and smoking and the prevention of spread of contamination or contaminated materials, together with the maintenance of "clean" areas, are of obvious importance. Prevention of unnecessary exposure to radiation is a prime consideration.

12. INSTRUMENTATION

a. Since the human body is not naturally equipped for the detection and measurement of ionizing radiations, it is necessary that this be done by proper use of specially designed instruments. With the exception of photographic and a few specialized techniques, detection of the radiations is accomplished as a result of the ionizations produced by the radiations. Each ionization event involves the average transfer of about 33 electron volts, and results in the production of an ion pair. If ion pairs are in some medium which allows their free movement, and also within an electric field, they will tend to migrate, each according to its charge and the polarity of the imposed electric

field. The movement of these ions results in a very small current which is utilized after suitable amplification to indicate the presence of ionizing radiations.

b. Various instruments operate on modifications and application of this fundamental theory. The ionization chamber type instrument depends on the application of a voltage across the ionization chamber of sufficient magnitude to effect the collection of the formed ions without allowing appreciable recombination, and the current measured will be in proportion to the degree of ionization produced.

c. The Geiger-Muller (G-M) counters depend on the fact that under high voltages for acceleration in a gas-filled tube, the primary ions produced by the radiations may produce secondary ions in their paths, and this process is repeated and multiplied so that even a single ion pair originally formed theoretically can be registered. All similar instruments present many technical problems in addition to the electronic circuit difficulties. Some of these include the choice of the wall of the collecting chamber to allow entrance of vary short-range radiations, and the design of the entire instrument for portability, durability and accuracy. Electronic difficulties are encountered because of the high voltages utilized, the need for specially designed resistors, tubes, and other circuit components, and the difficulty in maintaining an electronic balance of the circuit under continuing usage. The detection and measurements of these

currents of the order of 10^{-9} (0.000000001) amperes involves many specialized procedures.

d. Another method of detection and measurement is the use of photographic emulsions. The action of radiations on photographic emulsions results in a darkening of the processed film and this results in a measure of the radiation in terms of the degree of darkening with respect to the total exposure. Available photographic methods require careful film processing technique, calibration against a known source, and reading of results in a comparator or densitometer. The advantages of a film badge are that it provides a small, inexpensive means of detection which is also a permanent record.

e. Other methods under development and consideration include devices which are intended to provide a direct indication of total exposure received as personnel exposure indicators. Modified ion chambers are used as individual pocket-type dosimeters. Chemical devices under development depend upon colorimetric changes which occur as a result of exposure to radiation. Other methods incorporate the detection of a fluorescence produced in certain crystal structures by radiation. In addition, these scintillation type counters provide a wide range of intensity response, and may solve many problems of present G-M and ionization chamber instruments, although the problems of spectral sensitivity and the necessity for very high voltages for the stages of subsequent amplification still present developmental difficulties.

SECTION II

OPERATIONAL ASPECTS

13. EXPOSURE EFFECTS ON COMBAT EFFICIENCY

Section I of this handbook has presented the general background of the medical effects of the atomic bomb with special emphasis on the biological effects of ionizing radiation. The fact must be accepted that under field conditions, certain amounts of radiation will be accepted along with the other hazards of war on a calculated risk basis. A troop commander in the field must therefore know what effect an exposure to external ionizing radiation will have on the combat efficiency of his command. Further, he must have a reliable indication of the effect of both acute and recurrent exposure of personnel. Medical personnel will act as advisor to the commander on these subjects to enable him to make a reasonable decision on this calculated risk basis. At the same time the medical officer should take into consideration the added medical or logistical support required if it is expected that the calculated exposures are expected to produce casualties in the command.

a. The following effects may be expected in combat personnel exposed to external gamma radiation under field conditions over a short period of time.

Table IV

50r —No casualties. No reduction in combat effectiveness.

100r—2 percent may be casualties (nausea and/or vomiting) for a short period of time. No evacuation contemplated. No significant reduction in combat effectiveness.

150r—25 percent casualties in a few hours. First definite reduction in combat effectiveness. 50 percent of the casualties in this group will have to be evacuated.

200r—SD/50. All must be evacuated as soon as possible. 50 percent will be combat non-effectives.

300r—Approximately 20 percent deaths. All need evacuation immediately. All are combat non-effectives.

450r—50 percent deaths.

Over 650r—Lethal dose, but not necessarily for all so exposed.

The references to *lethality* in this compilation presuppose no medical care. If affected personnel are evacuated through medical channels, the fatalities will be substantially reduced, particularly in the 300r to 400r range. The nausea and vomiting which in the lower exposure range is very difficult to relieve by ordinary field medical treatment, may temporarily reduce the combat effectiveness of a field force. If the exposure time of radiation is increased to 24 hours, the effects may be substantially reduced.

b. Under certain conditions the effect of low dose recurrent exposure would be important in estimating the operational efficiency of personnel. The question may be asked as to the maximum

dosage personnel can receive at weekly intervals and still maintain operational combat efficiency. It is felt that personnel may be exposed to 25r gamma radiation delivered in a few hours or less at weekly intervals for 8 weeks and still maintain operational efficiency. This recurrent 25r gamma exposure applies also to Air Force crews on combat missions.

14. BETA RADIATION

All previous discussion has been concerned with gamma radiation. Beta radiation from fission products following a contaminating atomic explosion may present a problem under certain circumstances. Beta radiation under field conditions will always be present in association with gamma. For survey purposes the Beta intensity is not significant and need not be measured unless the total gamma flux is greater than 300r. It will suffice to remember that a beta hazard is present. The fission product ratio of gamma to beta is approximately 10 to 1. The beta rep necessary to affect field combat effectiveness is 3000 to 5000 rep. This assumes a fission product source with a beta energy of approximately 1 mev.

15. FOOD AND WATER CONTAMINATION

a. Following an air burst there will be no significant contamination of food and water, but this will not be true following a contaminating burst. Food and water in the open may be contaminated to a greater or lesser extent. A survey must be

made of these items to determine their potability. Even if an early survey reveals a relatively high degree of contamination it must be remembered that radioactive decay may be such as to make the material satisfactory for consumption in a short period of time. Food and water may be especially critical following an atomic disaster and every effort should be made to preserve them for use.

b. The following figures summarize the emergency level for beta-gamma activity in food and water immediately following a contaminating atomic explosion.

Table V

Time water is to be consumed	Safe		Low, acceptable risk	
	curies per cubic cm.	disintegrations per min. per cc	curies per cubic cm.	disintegrations per min. per cc
10 days	3.5×10^{-9}	7.7×10^{3}	$9. \times 10^{-8}$	$2. \times 10^{5}$
One month	1.1×10^{-9}	2.6×10^{3}	$3. \times 10^{-8}$	$7. \times 10^{4}$

It is emphasized that these levels of contamination are detectable with ordinary beta-gamma survey instruments.

16. COMBINED INJURY CONSIDERATIONS

a. The effect of combined injury, thermal plus nuclear, may be important in estimating evacuation requirements. Animal experimentation has shown that if a sub-lethal burn and a sub-lethal exposure to gamma radiation are combined, the re-

sultant injury may be lethal. Thus personnel who have combined injuries, which individually might not require evacuation, may need to be evacuated.

b. This combined injury effect becomes important when it is considered that for unshielded troops under field conditions, the initial gamma radiation is 100r at approximately 1 mile and the thermal flux at this distance is ten calories per cm^2. This thermal flux is sufficient to cause severe (third degree) burns on exposed body surfaces.

SECTION III

RADIOLOGICAL SAFETY GUIDE

17. GENERAL

The standards and values given herein for observance in laboratory and industrial operations dealing with ionizing radiation or radioactive materials are offered for easy reference in this handbook in view of the current interest in this problem. These values presuppose a continuing life time exposure and offer a substantial safety factor. In the event of atomic disaster or in specific military operations, for example, atomic weapons testing, these values may be revised in accordance with a previously determined scale of calculated risk.

18. RADIOLOGICAL SAFETY

In the field of Radiological Safety two types of radiation hazards are recognized, external and internal. Under conditions of atomic warfare, and in connection with industrial and laboratory atomic energy operations, it is possible for an individual to be exposed to both external and internal radiation hazards.

a. *External* radiation is that in which the source is located outside the body. Such radiation may be x-rays, gamma rays, neutrons or beta particles. These radiations are an external hazard because

of their ability to penetrate the tissues. Beta particles, although they have a limited range in tissue, may damage the skin. Alpha particles, because of their insignificant penetration, are not considered an external hazard. Even though it may seldom happen that the whole body is subjected uniformly to external radiation, it is nevertheless necessary, in the interest of safety, to assume that this always takes place, and to regard each exposure to external radiation as *total* body irradiation, rather than *limited* body irradiation, such as occurs in x-ray or radium therapy. An exception to this statement is exposure of the hands to beta rays. It is evident that further irradiation from an external source ceases immediately upon removal of the source, removal of the individual from the source, or the insertion of adequate shielding between the source and the individual.

b. Internal radiation is that type of hazard which exists when radioactive materials enter the body by ingestion, inhalation, or through the skin as by way of an open wound. With the inclusion of the internal hazard from radioactively contaminated materials and the use of radioactive isotopes, the problem has become complex. In the evaluation of the internal hazard and the effects on the body, it is necessary, to consider——

(1) The mode of entrance of the radioactive material into the body (inhalation, ingestion or introduction through the broken skin).

(2) The amount of absorption, and selective localization of that material within the body.

(3) The amount and rate of excretion of the material.

(4) The routes of excretion of the material.

(5) The physical characteristics of the radiation from the material.

  (*a*) The nature and energy of the radiation

  (*b*) The half-life value

  (*c*) The toxicity of the source and/or its decay products

An internal source which diffuses throughout the body fluids will give an effective total body irradiation, while one which is deposited and held will produce a localized effect, probably an intense one. Materials which emit gamma, beta, and/or alpha particles, such as radium, plutonium, or other radioactive elements including fission products, may be absorbed and deposited within the body. These act as damaging agents which injure or destroy blood-forming organs and other tissues. Clinical evidence of injury may be apparent in a few weeks in severe cases, or may not appear for years in cases where smaller amounts of radioactive material have been absorbed. With internal radiation, in contrast to external radiation, the source is fixed in the tissues and its removal is limited by the rate of excretion of the element from the body and the natural radioactive decay of the element.

19. TOLERANCES

a. Terminology. The concept of a tolerance to radiation is based on the probability that a given

small amount of radiation can be absorbed by the body without producing any detectable permanent effects.

(1) Although the term "tolerance" is used in reference to dosage of radiation, there is no proof that living tissues are actually tolerant to ionizing radiation, even in the minute amounts everywhere present as normal background radiation (cosmic rays, radon, etc.). The term "Maximum Permissible Exposure" is a better term. *Accordingly, the word "tolerance" will be replaced by the term "Maximum Permissible Exposure" (MPE).*

(2) These MPE's do not represent limits within which there can be complete disregard of exposure. Exposure to ionizing radiation should be kept to an absolute minimum in all routine operations in which it is assumed that an individual will be exposed to ionizing radiation as a lifetime occupational hazard.

b. External Radiation. The MPE for total body radiation exposure is 0.3 r (0.3 rep) integrated over a period of a week acquired in a single or accumulated dose. It is recommended that exposure levels of 0.05 r (0.05 rep) or less per 24-hour period be maintained for routine operations. Integrated exposures greater than 0.3r/week require removal of the individual from further exposure until "recovery" can be effected, using 1 week as the time index of exposure.

(1) A local external radiation MPE of 1.0

rep/week is established for beta radiation exposure to the hands.

(2) Exposure to high energy particles from piles or accelerators such as cyclotrons, betatrons, etc. require special MPE considerations not within the scope of this guide.

c. Internal Radiation.

(1) No amount of plutonium or a similar alpha emitting element is ever considered tolerable. If exposure, by any means, is unavoidable, the following rules may be applied. The maximum permissible level for plutonium in the atmosphere, or for other alpha emitting heavy unstable elements, is tentatively set at 5×10^{-12} microcuries/cc of air for continuous exposure for 1 year. The object of this MPE is the prevention of the deposition of a total of more than 0.5 microgram of plutonium in the tissues. The MPE for radium fixed in the body is 0.1 microgram. These figures are considered to be lifetime MPE's.

(2) The maximum permissible level for air contamination by the more hazardous beta-gamma emitting isotopes (such as iodine, strontium, barium) is considered to be approximately 10^{-9} microcuries/cc of air. The general rule is to wear masks (see par. 23) when the content exceeds 10^{-9} microcuries per cc of air and to evacuate an area when the air content

exceeds 10^{-8} microcuries/cc of air of above-mentioned type of isotope. An alpha level of 5 x 10^{-12} microcuries/cc of air is considered to be the MPE.

d. Clinical Use. In the clinical use of radioactive isotopes, the regulations concerning the safe handling of isotopes as set up by the National Bureau of Standards will apply.

e. Food and Water. No food or water known to be or suspected of being radioactively contaminated will be consumed until carefully monitored. The level of food and water contamination by radioactive materials which is considered significant is 10^{-7} microcuries/cc. This again implies indefinite (unlimited) duration of consumption.

20. PERSONNEL REQUIREMENTS

a. It is necessary that the least possible number of persons required for efficient execution of any given task in a radioactive area be employed with a view to minimizing the number of individuals exposed. However, in any radioactive area a sufficient number of personnel must be employed to assure that no individual shall be exposed to more than .05 r/24 hours. In the event of accidental exposure in excess of this amount, it will be necessary for the individual to be absent from further exposure until sufficient time has elapsed to reduce the total exposure to the equivalent of .3 r/week.

b. Persons not under the control of the military will comply in all respects with these regulations when engaged in a military sponsored operation.

21. MEDICAL EXAMINATIONS

a. Pre-Examinations. Personnel, both civilian and military, *working* with radioactive materials or radiation, will be required to have a physical examination prior to commencing such duty. This examination will include a complete blood count, urinalysis, and chest x-ray. The x-ray of the chest may be made by any available technique including 35-mm microfilm. If a similar examination has been conducted during the past three months, a repeat examination will not be necessary provided a record of such examination is maintained on file.

b. Physical Requirements. The general physical requirements are those for active duty in the military service or for Civil Service employment.

c. In addition to the general physical requirements, the following findings are considered disqualifying for work entailing possible exposure to ionizing radiation:

(1) All exposed wounds, whether cuts, abrasions or ulcerations (except when working with sealed sources or x-ray).

(2) Total white count below 4,000 or above 12,000 (In cases where abnormal white cell count may be due to transient diseases or other conditions, re-examination should be made upon recovery).

(3) Persistently abnormal differential count.

(4) Total red blood count below 3.5 million or above 6.5 million.

(5) Any evidence of previous radiation in-

jury which is considered disqualifying by the medical examiner.

d. Recording of Examination. The results of these examinations will be recorded on standard service physical examination forms. Any evidence of chronic radiation injury shall be recorded. If known, a statement will be entered under "Remarks" giving the total previous exposure to radiation and the type of work performed. The transmission of physical examination forms will be through channels normal to individual services.

e. Follow-up-Examination. All personnel working in a radioactive area will have follow-up examinations at the discretion of Radiological Medical Officers. Examiners will be alert for signs of chronic radiation damage, such as lack of vitality, loss of appetite, weight loss, cracking of the skin of fingers, and excessive longitudinal corrugation and brittleness of the fingernails. These findings will be recorded on the physical examination form.

(1) Complete blood counts and urine examinations will be made at the time of such follow-up examinations.

(2) Individuals presenting abnormal findings should be removed from all exposure to radiation and be given an exhaustive study.

(3) Individuals engaged in work with radioactive material will receive a complete physical examination annually.

22. PHOTOGRAPHIC DOSIMETRY

a. Film badges shall be worn by all persons

working with radiation or radioactive materials and by all those entering a radioactive area. The degree of exposure shall be preserved as a permanent record and in each case will be made part of the individual's medical record.

b. The frequency of processing and reading of film badges will be left to the discretion of the Radiological Medical Officer. Individuals will be permitted to return to the areas of exposure only if the previous reading has been recorded and found to be below the established tolerance. If above the MPE, the individual shall not be permitted to return to the radioactive area until sufficient time has elapsed that his total exposure is within the normal MPE. For example, if a man receives 0.3 r on Monday, he will not be exposed to radiation until the following Monday.

c. Where exposure of individuals to x- or gamma radiation is likely to exceed tolerance, it is advisable to augment film badges with pocket dosimeters.

23. PROTECTION OF PERSONNEL

a. Protective Clothing. Clothing used by personnel working with radioactive materials will vary with the local situation and may include—

A plastic or hard hat, or other head covering as appropriate.

Safety glasses.

Suitable washable and/or disposable outer garment.

Underwear.

Appropriate footwear and/or disposable canvas "bootees."

Socks.

Gloves, canvas type for manual labor; surgical or other rubber gloves for laboratory work.

b. When such material is contaminated with beta plus gamma emitting radioactive materials and produces an indicated roentgen reading on a standard type of instrument of over 0.05 r/working day or is contaminated with an alpha emitting material, it shall be disposed of or decontaminated. For fission product contamination, the following are considered as limits for a 24-hour working day:

Thin side-wall GM tube (30–40 mg/cm^2 such as the AN/PDR-5)—7 mr/hr indicated beta plus gamma when measured with the tube parallel and not more than 6″ from the contaminated surface.

Thin end wall GM tube (2–4 mg/cm^2 such as the AN/PDR-27)—2 mr/hr indicated beta plus gamma with the thin window parallel and not over 6″ from the contaminated surface.

c. Personnel will wear respirators when indicated. It is not necessary to wear a protective mask while performing duties such as monitoring or inspecting under dust-free conditions.

(1) It must be borne in mind that the following operations are known to increase

the respiratory hazard: cutting, burning, welding, dry sweeping, filing, grinding, scraping, sand blasting and/or paint chipping in a radioactive or contaminated area.

(2) For work in a radioactive area where adequate supply of oxygen is present and where there are no toxic fumes or gasses, the following masks are authorized for use:

Any Standard gas mask with M–10 or M–10–A1 cannister.

Army Assault Mask with the M–11, E–12, or M–10–A1 cannister.

Navy Combat Mask, MK–IV with B–2 cannister.

Gas Mask M–9 with cannister M–9.

(3) If radioactivity is present in air in which a deficiency of oxygen exists, or is suspected to exist, or where noxious gases are present, the following breathing apparatus shall be authorized to be used:

Rescue Breathing Apparatus.

Positive Pressure Breathing Mask with uncontaminated air or oxygen supply.

Mask with self-contained air or oxygen supply.

If such equipment is used, it is essential that personnel be carefully instructed in its use and be familiar with the safety precautions pertaining thereto.

(4) After using the Army Assault Mask or

the Navy Combat Mask with the appropriate cannister, all cannisters will be monitored and disposed of if contaminated.

d. No matches, lighters, cigarettes, or other smoking articles, nor chewing gum, chewing tobacco, nor edible materials nor drinks shall be allowed in radioactive areas in order to eliminate the possibility of inhalation or ingestion of radioactive materials.

e. Any individual who sustains a physical injury or possible accidental over-exposure to an internal or external radiological hazard shall report immediately to the Radiological Medical Officer for evaluation and treatment.

f. To insure that the workers are adequately protected, a definite procedure for personnel decontamination must be developed and rigidly followed at every activity where particulate radiological contamination is possible. A change station or decontamination procedure must be established for this purpose.

g. Radioactive or contaminated areas will be identified by adequate visual markings.

24. RESPONSIBILITY

Responsibility for the safety of personnel in a radioactive area rests with the commanding officer who acts on the advice of his Radiological Safety Staff. This staff will normally consist of line and medical officers especially trained in the evaluation of radiological hazards. Their decisions are

based upon monitoring and/or laboratory procedures.

25. CLEARANCE

a. "Operational Clearance" implies that contamination exists and special operating procedures are required. "Final Clearance" indicates that ships, aircraft, and other material require no further control from the standpoint of radiation.

b. Operational clearance for ships, aircraft or heavy equipment may be granted by the commanding officer when he is assured by the Radiological Safety Staff that the personnel tolerance limit will not be exceeded by their use. Time intensity factor and operational necessity must be considered. In peace time a 0.3 r/week will ordinarily not be exceeded.

c. Contamination with an alpha emitting substance requires specific clearance by the commanding officer after careful evaluation of the ingestion and inhalation hazard by the Radiological Safety Staff. Surface contamination giving a maximum reading of less than 500 counts/minute above background is generally considered to be within tolerance limits.

26. WASTE DISPOSAL

The following levels for waste disposal have been approved by the Atomic Energy Commission.

a. Any type of radioisotope can be buried in the earth, if the radioisotope is uniformly diluted

with nonradioactive isotopes of the same element in the same chemical form provided that no more than 4.15 ergs per gram of element were dissipated per day, that the burial is made only in suitably selected areas in possession of the user, and that the material is buried at a minimum depth of 5 feet.

b. Radioiodine (iodine 131) may be discharged from an institution into the main sewer, provided that to each millicurie of radioiodine discharged one gram of potassium iodide is added at the time of disposal, that radioiodine will be diluted to 10 microcuries per liter in the sewerage outlet from the institution into the main sewer, that regular surveys are made of plumbing fixtures, and that appropriate surveys are made before repairing the plumbing between the disposal outlet and the main sewer.

c. Radiophosphorus (phosphorus 32) may be discharged into the sewer, provided that it is diluted to 0.1 microcurie per liter in the sewerage system that each millicurie is diluted with 10 grams of stable phosphorus as phosphate at the time of discharge, that the maximum activity disposed of in any one institution does not exceed 200 millicuries per week, that appropriate radiation surveys are made before repairs are made to the plumbing and disposal outlets to the main sewer, and that the sewage does not enter directly into fresh water systems.

d. Radiocarbon (carbon 14) may be exhausted in the air, provided that no person shall be exposed to the inhalation of air containing greater than 0.01 microcurie per liter and that particulate matter is filtered from the exhaust air.

27. SAFETY INDOCTRINATION

In order that personnel working in a radioactive area may be properly informed as to the hazards and as to the safety measures to be observed, it is necessary that initial and continued indoctrination be provided. It is particularly important that those in immediate charge of working parties be cognizant of their specific responsibilities in regard to the supervision and execution of safety measures.

28. SUMMARY OF PERMISSIBLE LABORATORY AND INDUSTRIAL EXPOSURES

These are for lifetime exposures to radiation and are not to be interpreted as rules of field practice.

a. External Radiation.

(1) Total body exposure

0.3 (0.3 rep) integrated over a period of a week obtained in a single or accumulated dose. 0.05 r (0.05 rep) or less/24 hours for routine operations. Integrated exposures greater than 0.3 r per week require removal from further exposure until "recovery" can be effected using 1 week as the time index of exposure.

(2) Local external
1.0 r/week for beta radiation exposure to the hands.

(3) Individuals working
with external radiation for short period not to exceed 2 years.
1.25 r/month—single exposure allowable if no further exposure that month.

(4) Particle accelerators
and neutron exposures.
Special tolerance consideration not in scope of publication.

b. Internal Radiation.

(1) Plutonium or heavy
metal alpha emitters.
5×10^{-12} microcuries/cc of air for continuous exposure for 1 year.
Plutonium
0.5 microgram within the body.
Radium
0.1 microgram within the body.

(2) Air contamination by
more hazardous betagamma emitters.
10^{-9} microcuries/cc air. General rule is to wear masks when content exceeds 10^{-9} microcuries/cc air and to evacuate area where air content exceeds 10^{-8} microcuries per cc air.

(3) Air contamination
alpha.
5×10^{-12} microcuries/cc air.

(2) Food and water contamination
10^{-7} microcuries/cc.

c. Physical Requirements.

(1) General physical requirements are the same as required for active duty in the military service.

(2) In addition to the general physical requirements, the following findings are considered disqualifying for work entailing possible exposure to ionizing radiation;
All exposed wounds, whether cuts, abrasions or ulcerations (except when working with sealed sources or x-rays).
Total white count below 4,000 or above 12,000 (in cases where abnormal white cell count may be due to transient diseases or other conditions, re-examination should be made upon recovery).
Persistently abnormal differential count.
Total red blood count below 3.5 million or above 6.5 million.
Any evidence of previous radiation injury which is considered disqualifying by the medical examiner.

d. Protective Devices.

(1) Dosage measurement
Film badges worn by all in radioactive areas, pocket dosimetors if danger of exceeding tolerance.

(2) Respirators

Areas with adequate oxygen and no toxic fumes or gases:

Army Assault Mask with M–11, E–12, or M–10–A1 cannister.

Navy Combat Mask, MK–IV, B–2 cannister.

Areas with oxygen deficiency or where noxious gases exist:

Rescue breathing apparatus.

Positive pressure mask.

Mask self-contained air or oxygen supply.

e. Waste Disposal.

(1) Iodine ^{131}

Radioiodine may be discharged into the main sewer, provided that to each millicurie of radioiodine discharged one gram of potassium iodide is added, that radioiodine will be diluted to 10 microcuries per liter in the sewerage outlet from the institution into the main sewer, that regular appropriate surveys are made.

(2) Phosphorus ^{32}

Radiophosphorus may be discharged into the sewer when diluted to 0.1 microcurie per liter in the sewerage system, and diluted at time of discharge with 10 grams of stable phosphorus as phosphate provided that no institution's disposal exceeds 200 millicuries per week, and that appropriate surveys are made and the sewage does not enter directly into fresh water systems.

(3) Carbon ^{14}

Radiocarbon may be exhausted in the air, provided that no person shall be exposed to the inhalation of air containing greater than 0.01 microcurie per liter and that particulate matter is filtered from the exhaust air.

f. Clearance.

Operational

Implies that contamination exists and special operating procedures are required. Clearance granted by commanding officer on technical advice of Radiological Safety Staff members. In routine peacetime operations 0.3 r/week ordinarily will not be exceeded. Alpha contamination less than 500 counts per minute.

APPENDIX
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GLOSSARY

Alpha particle—A helium nucleus, consisting of two protons and two neutrons, with a double positive charge.

Beta particle—A high speed electron.

Betatron—A mechanism for accelerating beta particles.

Curie—Standard measure of rate of radioactivity decay; 3.7 x 10^{10} disintegrations per second.

Cyclotron—A machine for the acceleration of charged particles.

Decay—Disintegration of the nucleus of an unstable element by the spontaneous emission of charged particles and/or photons.

Decontamination—Removal of radioactive materials.

Dose (dosage)—Amount of radiation delivered to a specified area or volume, or to the whole body.

Dosimeter—Instrument used to detect and measure an accumulated dosage of radiation.

Electron—Negatively charged particle which is a constituent of every atom. Unit of negative electricity.

Electron volt—Amount of energy gained by an electron in passing through a potential difference of 1 volt.

Erg—Unit of work done by a force of 1 dyne acting through a distance of 1 cm.

Film badge—A pack of photographic film used for approximate measurement of radiation exposure, for personnel-monitoring purposes.

Gamma rays—A high frequency electromagnetic radiation with a range of wave length from 10^{-9} to 10^{-12} cm, emitted from the nucleus of an atom.

Geiger-Mueller (G–M) Counter—Highly sensitive gas-filled radiation-measuring device which operates at high voltages.

Half-life—Time required for a radioactive substance to lose 50 percent of its activity by decay.

Ion chamber—Container of gas in which an electric field exists because of a system of charged electrodes.

Ion density—(See Specific ionization).

Ionization—The process whereby a neutral atom or molecule is split into positive and negative ions.

Isotopes—One of two or more forms of an element having the same atomic number (nuclear charge) and hence occupying the same position in the periodic table.

Mev—Million electron volts.

Microcurie—One millionth of a curie.

Microgram—One millionth of a gram.

Millicurie—One thousandth of a curie.

Milligreps—One thousandth of a roentgen equivalent physical.

MPE—Maximum permissible exposure.

Neutrons—Nuclear particles having no charge and a mass practically equal to that of a protron.

Photodosimetry—Determination of the accumulative dosage of radiation by use of photographic film.

Radiation—The transmission of energy through space in the form of electromagnetic waves.

Radioactivity—The phenomenon of giving off radiation during the spontaneous disintegration of atomic nuclei.

Radioisotopes—Isotopes which are radioactive.

Recombination—Formation of neutral atoms by combination of ions produced by radiation.

Rep—Roentgen equivalent physical, the amount of radiation other than x– or gamma physically equivalent to 1 r.

Roentgen—The quantity of x– or gamma radiation which produces 1 esu of positive or negative electricity in a cubic millimeter of air at standard conditions.

Specific ionization—Number of ion pairs per unit path.

X-rays—Penetrating electromagnetic radiations having wave lengths very much shorter than those of visible light.

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